MEASUREMENT OF THE J/ψ RADIATIVE DECAY INTO $f^0(1270)\gamma$

PLUTO Collaboration

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The J/ψ decay modes $f^0(1270)\gamma$ and $\rho\pi$ have been studied in e^+e^- collisions at 3.1 GeV center of mass energy leading to the $\pi^+\pi^-\gamma$ and $\pi^+\pi^-\pi^0$ final states. The $f^0\gamma$ decay branching ratio is measured to be $(0.20 \pm 0.07) \times 10^{-2}$, a value comparable to the J/ψ radiative decay rates into the $\eta\gamma$ and $\eta'\gamma$ channels. The J/ψ decay branching ratio into $\rho\pi$ is measured to be $(1.6 \pm 0.4) \times 10^{-2}$.

The relatively large measured J/ψ radiative decay rates [1–3] into $\eta\gamma$ (~0.1%) and $\eta'\gamma$ (~0.25%) in comparison to the $\pi^0\gamma$ mode (~0.007%) are currently attributed to a non-negligible charm–anticharm ($c\bar{c}$) quark component in the η and η' particles [4–8]. This assumption follows naturally once it is noted that the η and η' are already not pure $u\bar{u} + d\bar{d}$ and $s\bar{s}$ quark states. There is then no reason why a further significant admixture of the $c\bar{c}$ component should not be present in these particles. This $c\bar{c}$ component facilitates apparent Okubo–Zweig–Iizuka (OZI rule) violating J/$\psi \to \eta(\eta')\gamma$ radiative decay transitions with the photon being coupled to one of the J/ψ charmed quarks. Following these ideas it is expected that the J/ψ to $f^0\gamma$ decay rate is very small since the f^0 is nearly a pure $u\bar{u} + d\bar{d}$ state and should not have any appreciable $c\bar{c}$ component [8]. Alternatively the VDM allowed J/ψ decay into $f^0\gamma$ via the intermediate J/$\psi \to f^0\omega$ transitions, having a measured rate of $(0.40 \pm 0.14)\%$ [9], will result in an $f^0\gamma$ decay rate similar to the $\pi^0\gamma$ mode. In this letter we report our experimental results for the J/ψ decay into the $f^0\gamma$ channel studied in its $\pi^+\pi^-\gamma$ final state. In the same study we also investigated the J/$\psi \to \rho\pi$ decay mode in its $\pi^+\pi^-\pi^0$ final state.

The experiment was carried out with the PLUTO magnetic detector at the DESY electron–positron storage ring DORIS operated at 3.1 GeV center of mass energy. The detector consists of a superconducting solenoid having a 2 T magnetic field parallel to the beams. The useful magnetic volume of 1.4 m diameter and 1.0 m length is filled with 14 cylindrical proportional wire chambers used both for triggering and track recording. Two concentric layers of lead having 0.44 and 1.70 radiation lengths are also incorporated in the apparatus in order to detect photons and measure their flight direction. The trigger efficiencies for the $\pi^+\pi^-\gamma$

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and $\pi^+\pi^-\pi^0$ configurations, of interest in this work, are evaluated to be respectively ~73% and ~75%. Further details concerning the detector and its performance have been presented elsewhere [10].

Out of ~84 000 hadronic J/ψ decay events produced in the e^+e^- collisions we selected the two prong events associated with one γ, where the photon was detected via pair production or electromagnetic shower formation. From this sample 1650 events fitted the three constraints hypothesis

$$e^+e^- \to \pi^+\pi^-\gamma. \qquad (1)$$

In order to eliminate wrongly identified events and $e^+e^- \to e^+e^-$ QED background, we have imposed on the fitted sample of events a χ^2 cut of 20, a colinearity cut of 6° for the two charged particles and a 16° cut for the angle between the photon and any of the two charged tracks. In this way a total of 825 events remained for physics analysis.

The measured missing mass squared recoiling against the two charged tracks interpreted as pions is shown in fig. 1 for the 825 well fitted events. A clear peak at $MM^2 \approx 0$ is seen consistent with a missing photon or a neutral pion where only one of its decay photons converted or both photons produced two unresolved showers. Detailed Monte Carlo calculations simulating our experimental setup and analysing programmes have been made. From these calculations it is found that ~21% of the $\pi^+\pi^-\pi^0$ final state events are detected in PLUTO as two prong configuration associated with one photon yielding a satisfactory fit to hypothesis (1). In these fits the photon energy and flight direction are well within the errors of the parent π^0-meson values. Thus our fitted sample of events consists of a mixture of the $\pi^+\pi^-\gamma$ and $\pi^+\pi^-\pi^0$ final states.

In fig. 2 we show the Dalitz plot $M^2(\pi^+x^0)$ versus $M^2(\pi^-x^0)$ where x^0 stands for either a photon or a π^0-meson. Three clear populated mass bands are seen in the plot corresponding to the known $\rho^+\pi^-$, $\rho^-\pi^+$ and $\rho^0\pi^0$ decay modes of the J/ψ particle [11–13]. In fig. 3a the $M(\pi^+\pi^-)$ distribution is presented for the same data with events lying within the $\rho^\pm$ mass bands ($0.6 < M(\pi^\pm\pi^0) < 1.0$ GeV) removed. A strong signal for the ρ^0 is seen followed by a statistically significant (~4 standard deviations) resonance-like enhancement in the 1.2 to 1.3 GeV mass range which resembles in mass and width the isoscalar tensor

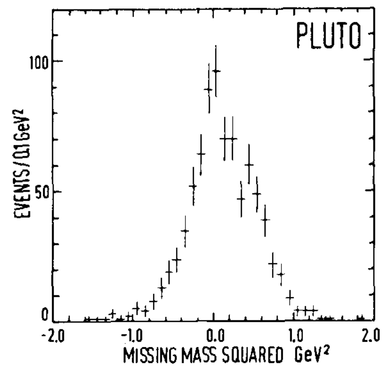

Fig. 1. Distribution of the measured missing mass squared recoiling against the $\pi^+\pi^-$ system for the well fitted $\pi^+\pi^-\gamma$ events after removing QED background.

$f^0(1270)$ meson. To ensure that this enhancement is indeed formed in the $\pi^+\pi^-$ system, we have reanalysed our data assuming different mass assignments for the charged tracks. No source for the enhancement other than the $\pi^+\pi^-$ system was found.

The combined mass distribution for the π^+x^0 and π^-x^0 systems is shown in fig. 3b where events lying within the ρ^0, ρ^- and ρ^0, ρ^+ mass bands respectively were removed. A strong signal for the $\rho^\pm$ is seen but no evidence is present for an enhancement in the 1.2 to 1.3 GeV mass region. Hence the enhancement seen in the $\pi^+\pi^-$ system cannot be attributed to the $I = 1$ $\rho'(1250$ [14, 15] in association with a π^0-meson. On the other hand the association of a $\rho'^0(1250)$ with a photon is forbidden by c-invariance. Alternatively the assignment of the $\epsilon(1200)$ resonance [14] to the enhancement in the data is rather unlikely. The $\epsilon(1200)$ width deduced from $\pi\pi$ partial wave analyses is ~600 MeV whereas the enhancement in the data is by about a factor four smaller. We thus conclude that the enhancement seen in the data is to be identified with the $J^{PC} = 2^{++}$ $f^0(1270)$ meson. From c-invariance it further follows that we do observe the $J/\psi \to f^0\gamma$ radiative decay transition in its final $\pi^+\pi^-\gamma$ state.

The $M(\pi^+\pi^-)$ distribution shown in fig. 3a was fitted by a linear combination of a polynomial background and two Breit–Wigner resonance shapes to account for the ρ^0 and f^0 mesons. A satisfactory fit was obtained for the mass and width values

$$m_{\rho^0} = 0.78 \pm 0.02 \text{ GeV}, \quad \Gamma_{\rho^0} = 0.13 \pm 0.02 \text{ GeV},$$

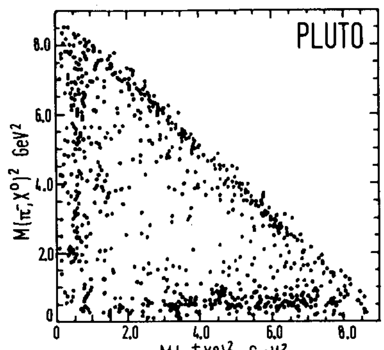

Fig. 2. Dalitz plot of $M^2(\pi^- x^0)$ versus $M^2(\pi^+ x^0)$ where x^0 stands for either a photon or a π^0-meson.

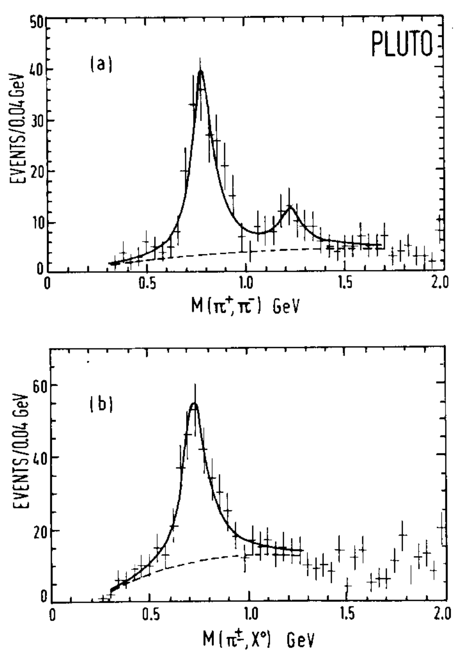

Fig. 3.(a) The $M(\pi^+\pi^-)$ distribution of the $\pi^+\pi^-\gamma$ sample excluding events lying in the ρ^+ and ρ^- mass bands. (b) Combined $M(\pi^+ x^0)$ and $M(\pi^- x^0)$ distribution for the $\pi^+\pi^-\gamma$ sample where x^0 represents either a photon or a π^0- meson. Events lying within the ρ^0, ρ^- and ρ^0, ρ^+ mass bands respectively were removed. The solid lines represent the best fit to the data, the dashed lines represent the estimated backgrounds.

and

$$m_{f^0} = 1.23 \pm 0.04 \text{ GeV}, \quad \Gamma_{f^0} = 0.13 \pm 0.05 \text{ GeV},$$

in agreement within errors with accepted values for these resonances. The observed number of events in the ρ^0 and f^0 peaks as found by the fit are 183 ± 16 and 35 ± 10 respectively. Similar fits were made for the $\pi^+\pi^0$ and $\pi^-\pi^0$ mass distributions to determine the fraction of ρ^+ and ρ^- in the data.

To evaluate the J/ψ decay branching ratios into $\rho\pi$ and $f^0\gamma$ we have used a Monte Carlo programme to calculate our overall experimental efficiencies. In addition we have examined with similar programmes the contributions to our ρ^0 signal from the J/ψ decay modes $\eta'\gamma$; $\eta' \to \rho^0\gamma$ and $K^{*0}\bar{K}^0$ $(K^0\bar{K}^{*0})$ channels where the $K^\pm$ mesons were wrongly interpreted as pions. We estimate that the contributions from these two decay modes to the ρ^0 signal are respectively 5 and 4 events. Similar contributions from the $K^{*-}K^+$ and K^-K^{*+} channels to the ρ^- and ρ^+ signals were also estimated. The contamination to our $f^0\gamma$ signal from the $J/\psi \to f^0\omega$, $\omega \to \pi^0\gamma$ channel is evaluated to be one event.

In this way we obtain

$$\Gamma(J/\psi \to \rho^0\pi^0)/\Gamma(J/\psi \to \rho^\pm\pi^\mp) = 0.53 \pm 0.15,$$

in agreement within errors with previously reported values [11, 13] and the expected value of 0.5 for the $I = 0$ assignment to the J/ψ particle. For the relative decay rate of J/ψ to $f^0\gamma$ and $\rho\pi$, corrected for all f^0 decay modes, we obtain

$$\Gamma(J/\psi \to f^0\gamma)/\Gamma(J/\psi \to \rho\pi) = 0.13 \pm 0.05.$$

Using the total number of hadronic J/ψ decay events seen in the experiment corrected for all losses we finally obtain

$$\Gamma(J/\psi \to f^0\gamma)/\Gamma(J/\psi \to \text{all}) = (0.20 \pm 0.07) \times 10^{-2},$$

and

$$\Gamma(J/\psi \to \rho\pi)/\Gamma(J/\psi \to \text{all}) = (1.6 \pm 0.4) \times 10^{-2},$$

corresponding to the decay widths of 0.14 ± 0.05 keV and 1.1 ± 0.3 keV, respectively. The overall $J/\psi \to \rho\pi$ decay rate given above is essentially the same when calculated from $3 \times \Gamma(J/\psi \to \rho^0\pi^0)$ or by adding up all the three $\rho^+\pi^-$, $\rho^-\pi^+$ and $\rho^0\pi^0$ measured decay channels. The value obtained here for $\Gamma(J/\psi \to \rho\pi)$ is somewhat higher but still consistent within errors with previously reported values from other experiments [11–13].

In conclusion, the measured $J/\psi \to f^0\gamma$ decay rate is found to be of the same order as that of the $f^0\omega$ decay channel. Hence the description of the $f^0\gamma$ decay mode in terms of an intermediate $J/\psi \to f^0\omega$ transition has to be abandoned. The $J/\psi \to f^0\gamma$ rate is also comparable to the $\eta\gamma$ and $\eta'\gamma$ decay rates and obviously much larger than the $\pi^0\gamma$ mode in contrast to what one may expect from the current theoretical ideas [4–8]. In fact it appears as if the $c\bar{c}$ admixture in the isoscalar $C = +1$ mesons is rather independent of their light quark composition.

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References

[1] W. Bartel et al., Phys. Lett. 66B (1977) 489.
[2] W. Braunschweig et al., Phys. Lett. 67B (1977) 243.
[3] B.H. Wiik and G. Wolf, Electron–positron interactions, DESY report 77/01 (1977).
[4] R.N. Cahn and M.S. Chanowitz, Phys. Lett. 59B (1975) 277.
[5] T.F. Walsh, Nuovo Cimento Lett. 14 (1975) 290.
[6] H. Harari, Phys. Lett. 60B (1976) 172.
[7] A. Kazi, G. Kramer and D.H. Schiller, Acta Phys. Austriaca 45 (1976) 65, 195; Nuovo Cimento Lett. 15 (1976) 120.
[8] T.F. Walsh, Short psion tour, DESY report 76/13 (1976).
[9] F. Vannuci et al., Phys. Rev. D15 (1977) 1814; PLUTO Collaboration, J. Burmester et al., DESY report 77/50 (1977); Phys. Lett. 72B (1977) 135.
[10] L. Criegee et al., Proc. 1973 Intern. Conf. on Instr. for high energy physics (1973) 707; PLUTO Collaboration, J. Burmester et al., Phys. Lett. 66B (1977) 395.
[11] B. Jean-Marie et al., Phys. Rev. Lett. 36 (1976) 291.
[12] W. Braunschweig et al., Phys. Lett. 63B (1976) 487.
[13] W. Bartel et al., Phys. Lett. 64B (1976) 483.
[14] Particle Data Group, Review of particle properties, Rev. Mod. Phys. 48 (1976) S1, and references therein.
[15] S. Bartalucci et al., DESY report 77/59 (1977), submitted for publication.